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# INJECTION NOZZLE FOR A METALLIC MATERIAL INJECTION-MOLDING MACHINE

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention is directed to an improved injection nozzle for a metallic material injection-molding machine and particularly a metal alloy injection machine.

### 2. Related Prior Art

In metallic material injection technology the facing surfaces between the nozzle and the sprue bushing on the mold have been machined so as to be compliant with one another and designed so as to have substantial surface contact. In this design it was assumed that the carriage cylinders could apply sufficient pressure to the nozzle to prevent it from parting contact with the sprue bushing. However, it has been discovered that even when the highest acceptable force is applied at the interface between the nozzle and the sprue bushing, it is insufficient to prevent some parting at the interface. This parting at the interface creates a build up of injection material on the surfaces of the interface with the ultimate result that the interface may fail to seal and permit the leakage of the injected material with sometimes catastrophic results.

In the prior art designs, the mating geometry between the faces of the nozzle and the sprue bushing were designed to withstand the positive forces applied by the carriage cylinders and remain in positive sealing contact throughout a complete machine cycle. The mating surfaces of the nozzle and the sprue bushing might be flat, spherical, conical or any other geometric shape that would provide an acceptable area of positive contact. The positive force applied by the carriage cylinders to the interface between the sprue bushing and the nozzle was intended to overcome the reactive forces developed as a result of the injection pressure generated during injection and any dynamic forces created as a result of any energy transfer between the components of the machine involved in the injection process.

Unfortunately, it has been discovered that it is virtually impossible to provide adequate clamping force to prevent separation between the nozzle and the sprue bushing when injecting metallic material, particularly material in a thixotropic state, because such very high pressures are involved and the reactionary and dynamic forces reach such high and relatively uncontrolled levels that separation eventually occurs.

Japanese Patent 11048286 to Japan Steel Works Ltd. is a further example of a nozzle that will continue to have leakage problems when subjected to the injection pressures normally associated with metallic material injection. In that design, the nozzle has a projected cylindrical part that is inserted into a cylindrical recess in the mold. The two annular surfaces formed on the nozzle and the mold are held in annular contact so as to maintain the nozzle to mold interface sealed. It is the problem of maintaining such a seal that has been overcome by the present invention, which does not require that the nozzle be in facing contact with the mold.

## SUMMARY OF THE INVENTION

The primary objective of the invention is to provide a nozzle to sprue bushing interface in a metallic material injection-molding machine that will remain sealed during the injection cycle.

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Another object of the invention is to provide, in a metallic material injection machine, an injection nozzle that may move relative to the sprue bushing without losing sealing at the interface between the nozzle and the bushing.

A further object of the invention is to provide, in a metallic material injection machine, a seal between the machine nozzle and the mold that requires a minimal force to be applied between the mold and the nozzle to maintain a seal between them.

A further object of the invention is to provide, in a metallic material injection machine, a machine nozzle and sprue bushing design that does not require contact between the nozzle and bushing to maintain sealing between them.

The foregoing objects are achieved by extending the nozzle into the interior surface of the sprue bushing.

The invention provides an improved nozzle and sprue bushing for a metallic material injection molding machine. The sprue bushing has a cylindrical surface and the nozzle an annular portion. The annular portion snugly fits within the cylindrical surface to provide a sealing engagement between the surface and the portion when the nozzle engages the bushing. The surface and the portion are of sufficient length to permit limited axial movement therebetween without a loss of sealing between them. The actual seal may be provided by the close fit between the bushing and the nozzle or by slight seepage of the metallic material between the surfaces where it freezes and provides the necessary seal.

The invention provides, in a metallic material injection molding machine, an injection nozzle joined to an injection barrel of the injection molding machine, a stationary platen holding a portion of a mold and a sprue bushing mounted in the mold. The nozzle engages the sprue bushing when the metallic material is injected through the sprue bushing into the mold. The nozzle has a spigot portion which extends into a channel in the sprue bushing. An outer periphery of the spigot fits into the inside surface of the channel so as to create a seal between the surface and the periphery of the spigot or enable the metallic material to create the seal and thereby prevent loss of metallic material through the interface between the nozzle and the sprue bushing during an injection cycle.

The invention is useful in any metallic material injection or casting process that requires a sealed interface between a nozzle and a sprue bushing. The invention has been found particularly useful when injecting metallic alloys such as magnesium based alloys when in the thixotropic state.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the injector assembly for a metal injection-molding machine with which the present invention is useful.

FIG. 2 is a cross-section of the barrel section of the injector assembly shown in FIG. 1.

FIG. 3 is a schematic representation of a prior art nozzle and sprue bushing interface as used in a metal injection-molding machine.

FIG. 4A is a plan view of the nozzle and sprue bushing interface in accordance with the present invention.

FIG. 4B is a view of the section 4B-4B of the nozzle and sprue bushing interface illustrated in FIG. 4A.

FIG. 5 is a cross-section of the sprue bushing and nozzle interface when the nozzle is in engagement with a sprue bushing in a mold on a stationary platen.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2, the injector assembly 10 includes an injection barrel 11 having an extruder screw 12

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for feeding thixotropic metallic material toward a nozzle 13. Carriage cylinders 14 move the assembly 10 toward and away from the stationary platen 15 and clamp the assembly 10 into place with the nozzle 13 in operative association with a sprue bushing connected to a mold which is mounted between stationary platen 15 and a movable platen (not shown) in a manner well-known in the art. Tie-bars are connected to the stationary platen 15 at the four corners of the platen 15 as indicated at 17 and to the frame of the injection machine when the nozzle is in the injection position in a manner that is well-known in the art. The tie-bars ensure that the pressure is applied uniformly to the platen 15 and the mold mounted thereon in a manner that is also well-known in the art.

To enable injection of metallic material into a mold, the carriage cylinders 14 move the barrel 11 towards the stationary platen 15 until the nozzle 13 is in operative engagement with a sprue bushing in the mold. When the nozzle 13 engages the bushing, the carriage cylinders 14 clamp the assembly 10 in position for injection of metallic material into the mold.

A rotational source 18 rotates the screw 12 to move metallic material from a feed throat 19 to the nozzle 13. Heater bands 20, along the length of the barrel 11, heat the metallic material to the desired injection temperature. As the metallic material passes through the head portion of the screw 12, a non-return valve 21 enables the metallic material to drive the screw 12 back towards the injector housing 22. This creates an injection charge of metallic material at the head of the screw 12.

In operation, metallic material chips are fed in at the feed throat 19 on the barrel 11 of the machine. The chips are transported through the barrel 11 by the extruder screw 12 and simultaneously heated to a thixotropic state by the heater bands 20 located around the barrel. When sufficient metallic material for injection has been moved past the non-return valve 21, the screw 12 is then driven forward by an injection unit within the injection housing 22 to inject the metallic material into the mold. As the metallic material cools very quickly when it enters the mold it is essential that the metallic material be injected into the mold as quickly as possible so as to ensure that all parts of the mold are filled. To do this requires that the injection piston be moved quickly forward during the injection cycle and with great force. The high speed and force makes it very difficult to hold the nozzle 13 in contact with the sprue bushing throughout the injection cycle even though the nozzle 13 is positively clamped to the sprue bushing by the carriage cylinder 14 which, with the tie rods and tie bars, are set to fully resist any separation between the sprue bushing and the nozzle 13. In practice, it has been found that the nozzle 13 and sprue bushing do separate during the injection cycle.

Dynamic and inertial loads are initiated at various parts of the injection cycle. Metallic material solidifies in the nozzle in between each injection cycle to form a cylindrical "plug". At the start of each injection cycle, the injection cylinder is pressurized by hydraulic fluid which forces the screw to move forward and increases the pressure on the thixotropic metallic material in front of the screw, but behind the plug. Eventually, the force from the injection piston is sufficient to cause the plug to separate from the nozzle and blow into the mold along with the thixotropic metallic material. The injection piston continues to move forward and the screw forces the metallic material into the mold until the mold is filled. When the plug leaves the nozzle, it creates recoil forces, which act on the nozzle to reduce the sealing load at the interface with the sprue bushing. This reduction of

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sealing load can cause separation at the sealing interface and the consequent leakage of metallic material.

Another significant load occurs when the mold is full and the screw comes to an abrupt stop. The deceleration of the screw, piston, and metallic material in front of the screw creates additional forces on the nozzle and sprue bushing connection. The nozzle springs back and the sealing force is reduced, at the same time that the melt pressure is highest. This causes the metallic material to leak from between the seal faces of the nozzle and sprue bushing.

As shown in FIG. 3, the prior art nozzle 13' has a machined spherical surface 23 that substantially matches the spherical surface 24 of the sprue bushing insert 25 over a predetermined angle. The sprue bushing insert 25 provides thermal isolation between the nozzle 13' and the sprue bushing 16' so that the nozzle 13' is not excessively cooled by the bushing 16'. When the nozzle 13' is brought into pressure contact with the sprue bushing insert 25, the bushing insert 25 and nozzle 13' provide a complete seal so that the metallic material injected through the injection channel cannot escape from the injection channel. Unfortunately, as indicated above, the nozzle 13' and sprue bushing insert 25 do separate during the injection cycle and metallic material starts to build up on the sprue bushing insert 25 and nozzle 13' surfaces which have been machined to exactly match. This means that, over time, the connection between the nozzle 13' and sprue bushing insert 25 will fail and have to be replaced by a new nozzle and sprue bushing insert. This is expensive and time consuming and it would be desirable to find a connection that either would not fail or at least would function properly for many more injection cycles. The nozzle and sprue bushing interface shown in FIGS. 4A and 4B provides such a connection.

With the design shown in FIGS. 4A and 4B the nozzle 13" includes a spigot portion 26, which is machined to snugly fit inside the sprue bushing channel 27. The shoulder 28 on the nozzle 13" may or may not abut against the face 29 of the sprue bushing 16" and be held there by the pressure applied through the carriage cylinders 14. With this design it has been found that the nozzle 13" and sprue bushing 16" can, in fact, move axially with respect to one another without any dilatory effect on the process. While the metallic material may get between the wall of the sprue bushing 16" and the surface of the spigot portion 26 of the nozzle 13", it gets no further. The alloy solidifies in this area and prevents any further ingress toward the outside of the nozzle 13". The metallic material on the surface between the sprue bushing 16" and nozzle 13" is removed with the sprue when the molded part is ejected from the mold.

Accordingly, by this simple change in the shape of the nozzle, the problem of nozzle sealing failure has been overcome.

Furthermore, there are a number of further advantages to this design modification. For example, the nozzle shoulder 28 does not need to be in contact with the face 29 of the sprue bushing 16" so that wear on these surfaces can be avoided. Of course, a screw bushing insert like the one shown at 24 in FIG. 3 can be located on the end of sprue bushing 16" to further thermally isolate the nozzle 13" from the bushing 16" if the separation between face 29 and shoulder 28 provides insufficient thermal isolation.

A variety of metallic materials may be injected using the new nozzle, however, the nozzle works particularly well with metal alloys such as magnesium based alloys. The nozzle will also work with other metal alloys such as aluminum or zinc based alloys.